The Barley Growth Guide

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Print publication: 01/01/2006

HGCA

The barley growth guide

SCOTTISH EXECUTIVE

Winter 2005/06

Winter 2005/06

HGCA

Contents

The rationale for this guide

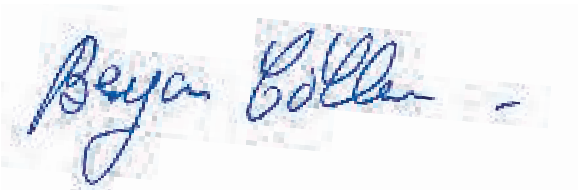
Winter and spring barley crops are grown throughout the UK for markets with differing requirements. The potential yield of this important crop is high, but on-farm performance can often be disappointing.

Improving performance depends on understanding how the crop develops and grows in the field. Such knowledge is vital to improve on-farm management and supporting research. This is why HGCA with the Scottish Executive Environmental and Rural Affairs Department funded a research project from 2002 to 2005 to provide data for a guide on barley, similar to *The wheat growth guide* (1997). The aim is to enable barley growers to identify where production may be falling short of potential.

The first step was to make a detailed analysis of high-yielding winter barley crops grown in different parts of Britain over three seasons. From this data 'benchmarks' were developed for each facet of barley development through the growing season. These benchmarks have been interpreted and summarised in this guide.

During the project, spring barley production increased in the UK, while the winter barley area fell. Therefore, each section of this guide includes information to highlight key differences between winter and spring crops.

This guide clearly illustrates that barley and wheat differ in many important respects and need different management techniques.



Bryan Collen
Chairman
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Managing barley growth

Managing your crop

Crop management plans need regular revision throughout the growing season in response to crop progress and to changing weather and soil conditions.

The management steps are to:

1. set targets
2. assess progress
3. adjust inputs
4. monitor success.

Assessment at each step is vital if management is to be optimised. Pests, weeds and diseases are regularly assessed. However, crops should also be monitored.

This guide, for the first time, provides a series of benchmarks of barley growth and development, and explains how they interrelate.

Locations of reference crop trial sites

Benchmarks are provided for the UK. and where needed for north and south as indicated above.

Words in italics, such as *Benchmark*, are defined in the Glossary.

What is a benchmark?

A benchmark is a quantitative reference point against which a crop's performance can be compared. The symbol is used in this guide to denote a specific *benchmark.*

There are many ways to achieve satisfactory yields. Therefore, while the benchmarks are compatible with good yields, they should not be regarded as a set of management targets. Benchmarks are intended to help growers – as well as agronomists and researchers – identify and evaluate key aspects of crop performance, eg dates of key growth stages or tiller production.

Pages 4–5 give benchmarks for important growth stages and values for key processes.

Developing the benchmarks

Each *benchmark* in this guide represents a median value derived from measurements made on the two-row winter barley variety Pearl. Trials were sown between 15 September and 10 October at six trial sites across Britain in each of the three harvest years 2002—04.

Full crop protection and lodging control was applied to minimise potential crop losses. Fertiliser use was for feed quality grain rather than for malting.

Different varieties and sowing dates outside the above range may reach key stages earlier or later than the benchmark date.

Where known, differences, for six-row winter barley and spring barley, are highlighted.

Using the benchmarks:

- **Set targets, considering variety, sowing date, soils and weather conditions.**
- **Assess crop progress against benchmark values.**
- **Modify current husbandry, where possible, to meet targets.**
- **Re-assess crop progress, and final performance.**
- **Amend future crop management in light of observations.**

Benchmarks at key growth stages

Decimal Code	Barley growth stages
	Seedling growth
GS10	First leaf through coleoptile
GS11	First leaf unfolded
GS13	3 leaves unfolded
GS15	5 leaves unfolded
GS19	9 or more leaves unfolded
	Tillering
GS20	Main shoot only
GS21	Main shoot and 1 tiller
GS23	Main shoot and 3 tillers
GS25	Main shoot and 5 tillers
GS29	Main shoot and 9 or more tillers
	Stem elongation
GS30	Ear at 1cm (pseudostem erect)
GS31	First node detectable
GS33	3rd node detectable
GS35	5th node detectable
GS37	Flag leaf just visible
GS39	Flag leaf blade all visible
	'Booting'
GS41	Flag leaf sheath extending
GS43	Flag leaf sheath just visibly swollen
GS45	Flag leaf sheath swollen
GS49	First awns visible
	Ear emergence
GS51	First spikelet of ear just visible
GS55	Half of ear emerged
GS59	Ear completely emerged
	Flowering
GS61*	Start of flowering
GS65	Flowering half-way
GS69	Flowering complete
	Milk development
GS71	Grain watery ripe
GS73	Early milk
GS75	Medium milk
GS77	Late milk
	Dough development
GS83	Early dough
GS85	Soft dough
GS87	Hard dough
	Ripening
GS91	Grain hard (difficult to divide)
GS92	Grain hard (not dented by nail)

* in some spring crops GS61 may precede GS59

GS21

	Overall	South	North
Main shoot + 1 tiller	**13 Nov**	10 Nov	15 Nov
Plants/m² *85% of seeds sown*	**305**	277	327
GAI	**0.3**	0.3	0.3

GS30

Ear at 1cm	Overall	South	North
Main shoot + 3 tillers	**2 April**	31 Mar	5 April
GAI	**1.4**	1.6	1.3
Shoots/m² *Shoot numbers start to decrease*	**1180**	1080	1280

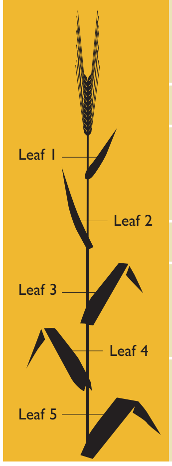
GS31

	Overall	South	North
First node detectable	**16 April**	13 April	18 April
Leaf 3 emerged	**15 April**	15 April	15 April
Leaf 2 emerged *Leaves emerge every 108°C days (day degrees)*	**25 April**	24 April	27 April
GAI *Canopy increases at up to 0.2 units/day until GS39*	**2.4**	2.6	2.3
N uptake (kg/ha) *About 35% of final N uptake*	**65**	67	63
Crop height (cm)	**11**	12	9
Total dry weight (t/ha) *Only 16% of final dry weight*	**2.4**	2.6	2.1

GS39

	Overall	South	North
Flag leaf (leaf 1) blade visible	**6 May**	3 May	9 May
Total leaf number *No further leaves emerge on main stem*	**14**	15	13
GAI	**5.1**	5.1	5.1
N uptake (kg/ha) *Uptake now slows*	**128**	122	133
Crop height (cm)	**45**	47	42
Total dry weight (t/ha) *About 35% of final dry weight*	**5.2**	5.1	5.3

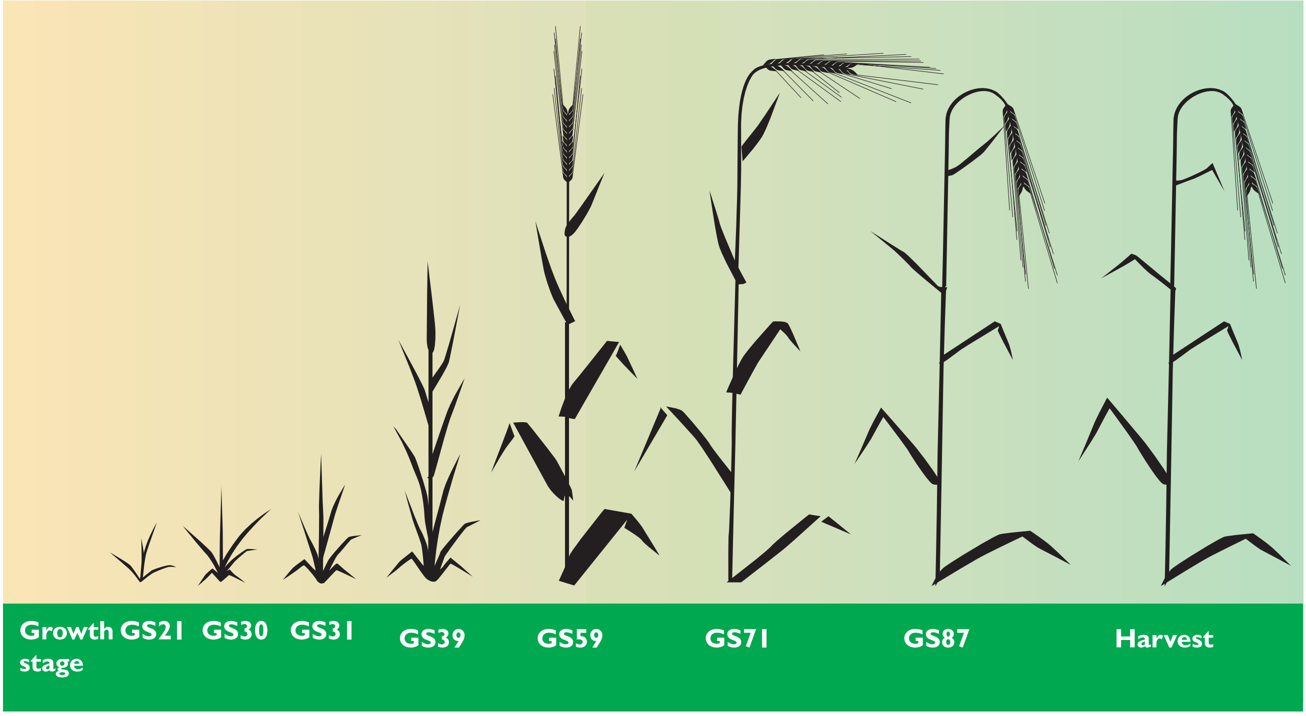
GS59



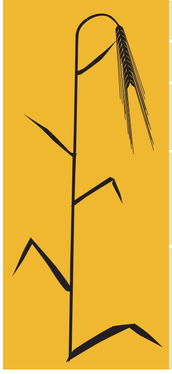
	Overall	South	North
Ear completely emerged	**26 May**	21 May	30 May
(also GS61 flowering starts at the end of ear emergence)			
Shoots/m²	**855**	835	875
GAI *Awned ears represent 10% GAI*	**5.8**	5.8	5.8
N uptake (kg/ha)	**163**	164	162
Crop height (cm) *Little further stem extension*	**87**	89	86
Total dry weight (t/ha) *About 80% of final dry weight*	**9.6**	9.6	9.6

GS71

	Overall	South	North
Grain watery ripe	**8 June**	5 June	11 June
GAI *Leaf loss lower in the canopy*	**5.0**	5.0	5.0
Crop height (cm) *No further extension occurs*	**93**	89	98
Stem dry weight (t/ha)	**7.4**	7.3	7.5

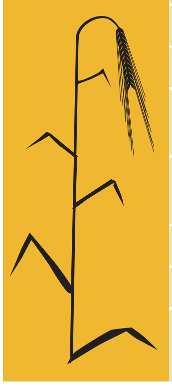


GS87



	Overall	South	North
Hard dough	**5 July**	28 June	14 July
GAI	**0.4**	0.3	0.6
Grain filling period (days)	**40**	38	45
Ripening period (days) *(45% to 20% moisture content)*	**20**	21	18
Total dry weight (t/ha)	**15.7**	15.4	16.1

Harvest



	Overall	South	North
	26 July	18 July	1 Aug
Total N offtake (kg/ha)	**181**	179	183
Shoots/m²	**775**	795	755
Stem weight (t/ha)	**6.4**	6.2	6.6
Grain weight (mg) *(15% moisture content)*	**46**	45	48
Grain specific weight (kg/ha)	**65**	65	65
Grain N (%)	**1.76**	1.80	1.73
Total dry weight (t/ha)	**14.8**	14.4	15.2
Grain yield (t/ha) *(15% moisture content)*	**8.8**	8.5	9.0

Development and growth – the basics

Some phases of development and growth have more effect on harvestable yield than others.

Management should maximise growth in those phases that influence yield most.

Each phase can be divided into:

- ***Development* – changes in the crop's structure, as defined by the Decimal Code.**
- ***Growth* – changes in crop size or weight.**

Development

Crop development is measured by progress through *growth stages*. Crop processes switch on or off at key stages (GSs 21, 31, 39, 59, 71 and 87).

Development can only be altered by variety choice and sowing date. Subsequent management decisions aim to influence growth during a developmental phase, eg by controlling disease or applying fertiliser.

The speed at which a crop progresses through each developmental stage is governed by:

- **Temperature** — warm conditions speed up development.
- **Vernalisation** — cool, not freezing, temperatures advance the start of flower initiation in young plants.
- **Photoperiod** — long days advance floral development.

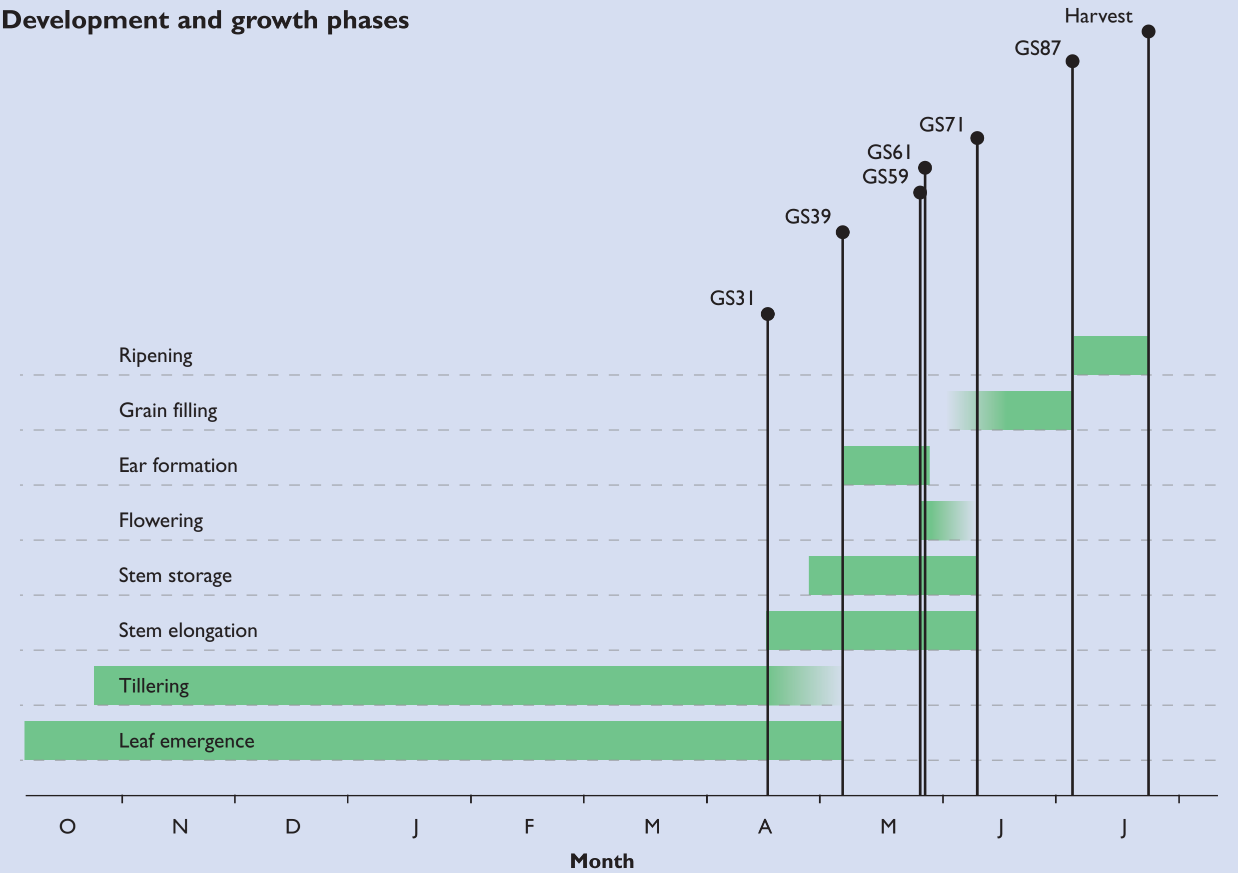
Sowing date

Sowing date has the greatest influence on early crop development. Later-sown crops pass through their developmental stages faster and complete each stage more quickly, than crops sown earlier. Typically, crops sown several weeks apart will mature within days of each other.

In an average season, winter barley crops sown after 10 October, reach key developmental stages later than the benchmark date. Any differences diminish over the season.

The window for sowing winter barley is narrower than for winter wheat. A low vernalisation requirement means barley is less suited to very early sowing, while yield declines faster when it is sown after mid-November. In the spring, barley begins reproductive development earlier than wheat and so may be more susceptible to frost damage.

Development and growth phases



Growth

Growth, the increase in crop size or weight, results from *photosynthesis*. It depends on:

- light energy falling on the *canopy*
- size of green canopy and hence light interception
- capacity of crop to utilise light energy and store dry matter.

Growth can only be managed by altering green canopy size.

Spring barley

Spring barley is typically sown from December until late April.

The crop is relatively frost-sensitive so early sowing is not common in the north. In a spring-sown crop, the three main phases (canopy formation, canopy expansion and grain filling) all last from six to eight weeks.

Speed of development differs little between varieties. Some varieties produce fewer tillers, making them less suited to late sowing. Spring varieties on the current *HGCA Recommended Lists* mature within a narrower period than do 2-row winter barley varieties.

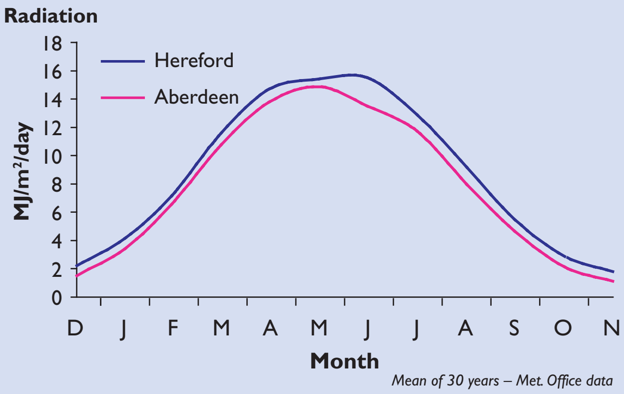
Maximising growth

Growth in any phase of a crop s life is maximised by bright, cool weather because:

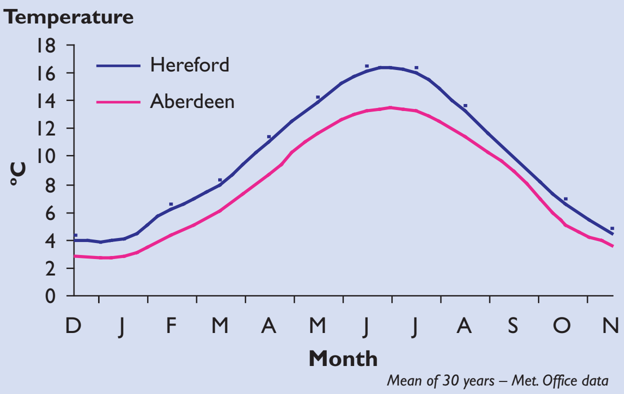
- high light energy maximises photosynthesis
- cool temperatures slow development and increase the length of any phase.

Summer light levels and temperatures are both lower in the north than in the south.

Daily incident radiation in Aberdeen in June is 96% of that in Herefordshire



In June, the average temperature in Aberdeen is 84% of that in Herefordshire



In the north, lower temperatures slow development and maximise growth. This results in high average yields in the north despite more cloudy days.

On cloudy days light energy is less than half that intercepted on sunny days.

Site and season effects can therefore be explained by variation in both light and temperature.

Establishment

Establishment can be divided into germination, emergence and overwinter survival.

For successful plant establishment seeds require moisture, warmth and oxygen.

Key Facts

- **Barley has limited ability to compensate for reductions in seed rates.**
- **Germination is driven by adequate soil moisture, temperatures above 0°C and oxygen.**
- **Speed of emergence is governed by soil temperature and sowing depth.**
- **Overwinter survival can be very variable, according to site and season.**

Seed rates and plant populations

In recent years many farmers have reduced winter wheat seed rates. This is possible because wheat can compensate by increasing ear size and number on each plant. There is less scope for barley to compensate by increasing grain number in each ear, as there is only one *floret* in each spikelet.

Spring population = 305 plants/m²

Calculating seed rate
Calculations need to work back from the target spring plant population to an autumn seed rate.

$$\text{Seed rate (kg/ha)} = \frac{\text{Spring population (plants/m}^2\text{)} \times \text{Thousand grain weight (g)}}{\text{Expected establishment (\%)}}$$

Germination

Seeds can only germinate if moisture is adequate; if this requirement is met, germination rate is controlled directly by soil temperature.

Initially, water penetrates the seed coat, softening the hard, dry tissues inside, the process of *imbibition*. Good seed:soil contact speeds up water transfer from soil to seed, which is particularly important in drier seedbeds. Water uptake activates the embryo and allows plant hormones to be transported through seed tissues.

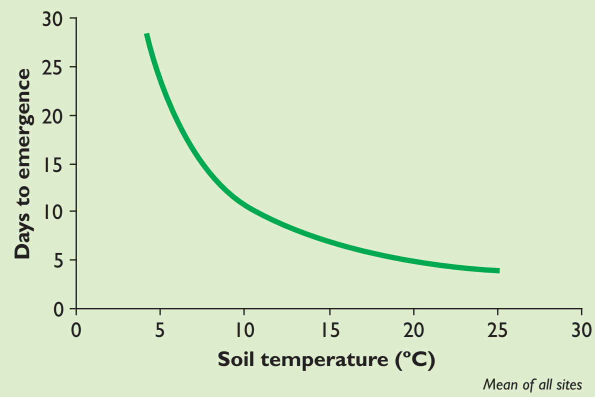
Very wet, or near saturated soil conditions reduce the oxygen diffusion rate. In such conditions, despite normal imbibition, oxygen becomes limiting and reduces germination.

Emergence

Temperature drives emergence. Temperature affects rate of both germination and emergence, so a measure incorporating both time and temperature – ie accumulated mean daily temperature from sowing – measured in *thermal time* (°C days), is used.

At the reference sites, crops reached 50% emergence in 150°C days. The thermal time was much higher where dry soil limited establishment. In autumn, as daily temperatures decline, crops take longer to emerge, but emergence accelerates as temperatures increase in spring.

Emergence in days at different soil temperatures



In the warmer south, the threshold of 150°C days is reached sooner than in the north.

Days to accumulate 150°C days

Sowing date	North (Aberdeen)	South (Herefordshire)
15 September	13	11
15 October	18	15
15 November	34	25
15 December	48	34
15 January	48	35
15 February	38	28
15 March	28	21
15 April	21	16

Mean of 30 years – Met. Office data

Thermal time to 50% emergence = 150°C days

Overwinter survival

Barley is generally more susceptible to overwinter plant loss than wheat. Overwinter survival is site dependent.

Losses can occur from frost heave, waterlogging and direct frost effects, as well as pests. Shallow, late sowing, low seed rates and manganese deficiency increase the risk of losses. Seedbed consolidation reduces the risk of frost heave.

Winter hardiness ratings of winter barley varieties are given in the *HGCA Recommended Lists*.

Overwinter survival = 85%

Spring barley

Ideally, the seedbed for spring barley should be fine and well-drained.

Early sowing, or poor seedbeds, may lead to reduced establishment, but early-sown crops tiller well to compensate.

In a good seedbed, between 80% (early-sown) to 95% establishment (late-sown) is typical. In a poor seedbed, establishment can vary from 55% (early) to 70% (late). Late spring drought may reduce establishment further.

Spring barley is less winter hardy than winter barley. Site selection is important when considering sowing spring barley early.

Seed rate

Spring barley, especially when drilled late, compensates less well than winter barley for reduced plant populations, so potential to reduce seed rates is less.

Drilling late-sown crops (after optimal date) at an increased seed rate reduces the risk of low ear numbers from poor tillering or establishment.

Action

Consolidate seedbeds in dry conditions to improve seed:soil contact, water uptake and germination.

At drilling

- **Avoid late and shallow drilling.**
- **Increase seed rate when sowing after the optimal dates to offset poor establishment or tillering.**
- **Consider pests, eg slugs and leatherjackets when determining seed rates.**

Prevent BYDV in winter crops if appropriate, by seed treatment or spraying against aphid vectors.

Correct manganese deficiency, which can decrease winter hardiness in autumn.

Select varieties with good winter hardiness for northern and exposed sites.

Nitrogen uptake

Barley is usually grown on sites with low soil N, so yield mainly depends on timing and rate of fertiliser applications.

Key Facts

- **Soil N rarely supplies all the N required. N applications can be used to manage canopy size.**
- **Over the season, N affects different aspects of canopy development.**

Pattern of uptake

Canopy size is directly related to N uptake throughout the crop's life.

Overwinter to mid–March
Early-sown crops are likely to experience good autumn growing conditions with increased N uptake, depending on soil N availability.

Mid-March to GS31
Rate of N uptake increases in mid-March as warmer conditions stimulate canopy expansion through more rapid leaf emergence and tillering.

Rate of N uptake = 1.2kg/ha/day
Total uptake = 65kg/ha by GS31

GS31–39
Rapid N uptake continues as canopy size increases through leaf emergence and tiller survival.

Rate of N uptake = 3.1kg/ha/day
Total uptake = 128kg/ha by GS39

GS39–59
N uptake slows as canopy size peaks and ears begin to form.

Rate of N uptake = 1.8kg/ha/day
Total uptake = 163kg/ha by GS59

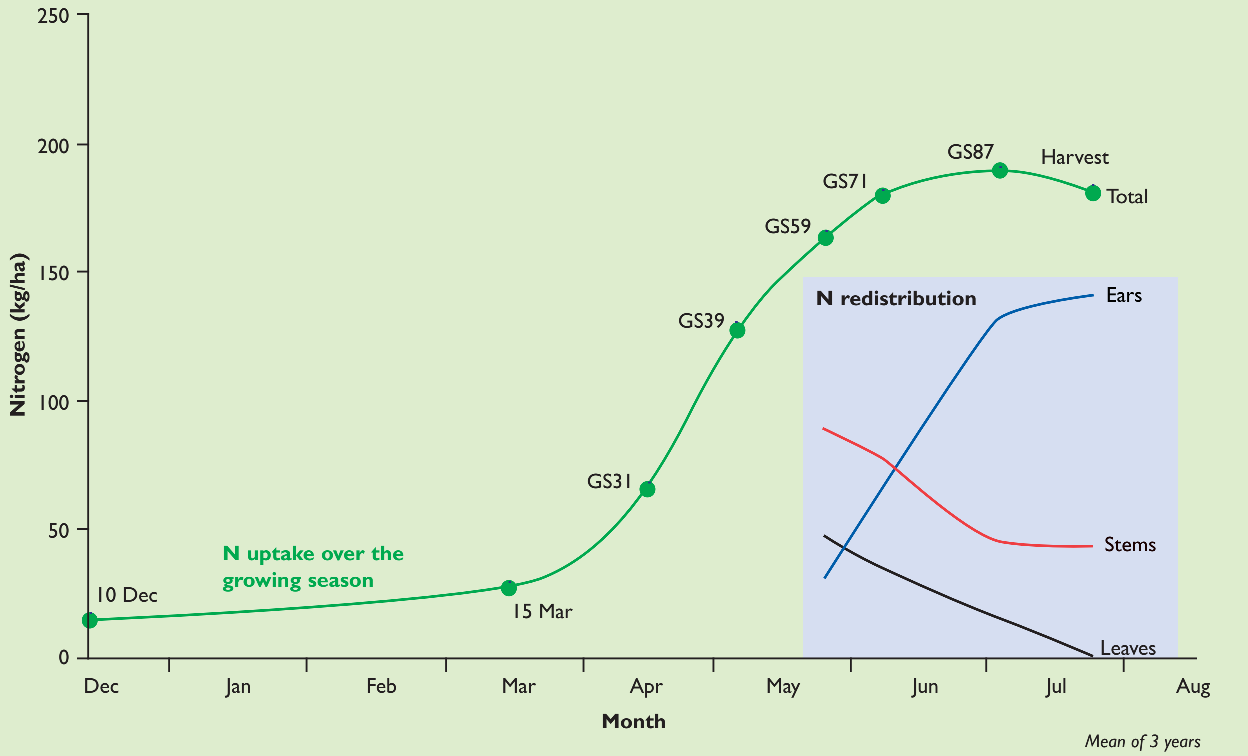
Nitrogen requirements

Barley is usually grown after winter wheat (a crop with a high nitrogen demand) on lighter low N status soils, which are prone to leaching.

Available soil N is likely to be no more than 60–80kg/ha on medium soils and less than 60kg/ha on light sands and shallow soils. Soil N is rarely sufficient for crop requirement. Unless adequate N is made available, shoot numbers and yield will be restricted.

N uptake = 28kg/ha/GAI unit

Nitrogen in the crop



After ear emergence (end-May), relatively little nitrogen is taken up and N is redistributed within the plant. Protein in leaves and stems transfer to form grain protein in developing ears.

Spring barley

The maximum N offtake in spring barley is 25–30% less than that in winter barley, ie 130kg N/ha at harvest.

Action

Time N applications to ensure N is available from mid-March to GS59.

Apply early spring N to encourage tillering and ensure adequate ear number/m².

Use late spring N to encourage rapid canopy expansion through tiller survival, and ensure sufficient grains/ear.

Avoid excess N applications later in the season which impairs quality due to high grain N.

Leaf emergence and tillering

The first leaf emerges from the *coleoptile* soon after drilling. Leaves then emerge continuously on main stems and tillers until the final leaf emerges.

***Tillering* is one of the most important processes governing canopy development and crop yield. Seed rates and N influence tiller numbers.**

Key Facts

- **Temperature drives speed of leaf appearance – rates differ between varieties and sowing dates.**
- **Thermal time controls number of leaves initiated.**
- **Tillering is affected by temperature, not location within the UK.**
- **Final shoot number is a key component of yield; ear number is correlated with yield.**

Phyllochron and leaf emergence

Temperature drives leaf emergence. The *phyllochron* (time taken for each leaf to emerge) is measured in thermal time (°C days).

Initially, winter barley leaves emerge rapidly during autumn. The rate slows overwinter, then accelerates in spring until the final leaf emerges in May at GS39.

Late-sown winter crops accumulate less thermal time to GS39 and produce fewer leaves. However, the phyllochron decreases in later-sown crops so the rate of leaf emergence increases.

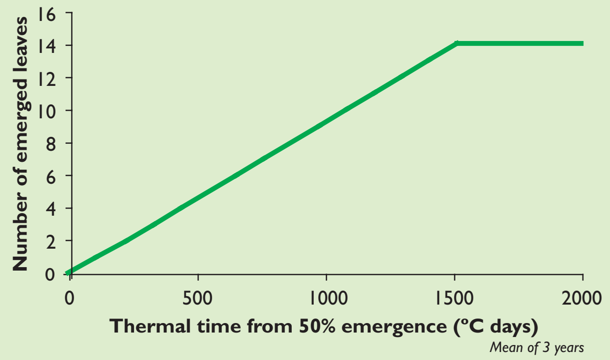
Barley varieties exhibit a daylength response that may influence rate of leaf emergence. Varieties vary in the relative influence of daylength and temperature on rate of leaf emergence. However, no current varieties are daylength insensitive.

Phyllochron = 108°C days
No location effect

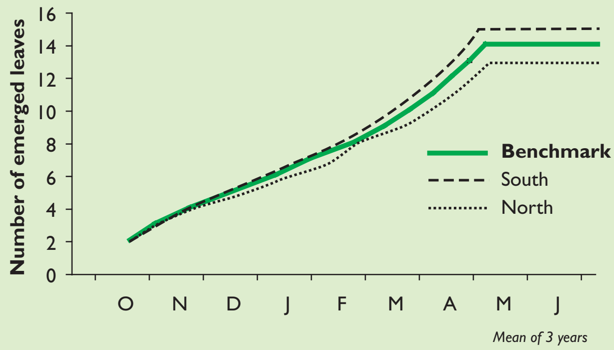
Number of leaves and thermal time

Crops usually produce fewer leaves at northern sites than at southern sites, as less thermal time is accumulated before the crop switches to reproductive development in cooler winter weather.

Thermal time and leaf emergence



Date and leaf emergence



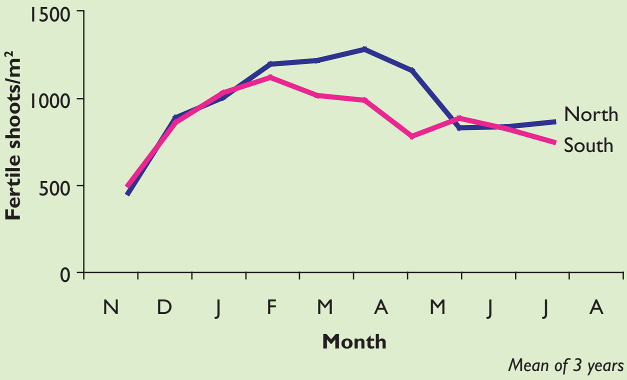
Number of leaves = 14
North = 13
South = 15

Control of tillering

Tillering, the production of shoots in addition to the main stem, occurs after leaf 3 emerges and continues until stem extension in the spring. Tillering is affected by temperature, water and nutrients. It determines ears/m^2 – an important yield component.

Reference crops tillered equally well at northern and southern sites. The process of tiller death began earlier at southern sites, but final ear numbers were similar at all locations.

Progress of tillering



Tillering starts rapidly in the autumn, slows over winter and can resume in the spring as temperatures and nutrient availability improve. Tillering may occur later, during stem extension, if spring drought restricts water and nutrient availability before moist conditions return.

Tiller numbers may be reduced by late sowing, delayed emergence, poor nutrient availability and low autumn temperatures. Early-sown crops tiller for longer and so compensate for low plant populations.

Shoot numbers by GS30 (2 April) = 1180 shoots/m^2
North (5 April) = 1280 shoots/m^2
South (31 March) = 1080 shoots/m^2

Final shoot number

Over the season, the maximum *shoot* number usually exceeds final shoot number. Increasing competition for both light and nutrients results in smaller, most recently formed tillers dying to make way for main yield-forming shoots.

The final fertile shoot number is similar throughout the UK but is reached by mid-March in the south, mid-April further north.

Final shoot number = 775/m^2
3 shoots/plant

Spring barley

Spring barley generally produces fewer (8–10) leaves than winter barley. Phyllochrons are around 10% less than in the winter crop, depending on variety, as less time is available for canopy expansion.

Tiller initiation, but not appearance, stops just after stem extension ends. Spikelets are initiated after two leaves have unfolded.

Final ear numbers are similar in spring and winter varieties; however, spring crops produce fewer tillers.

Action

Review N timing and rate to remedy low tiller numbers.

Ensure fungicide strategies protect the last 3–4 leaves.

Choose an early-maturing spring barley variety for late sowing.

Canopy expansion and senescence

Canopy size is determined by both leaf emergence and tiller numbers.

Managing canopy size and *senescence* is the key to maximum yield.

Key Facts

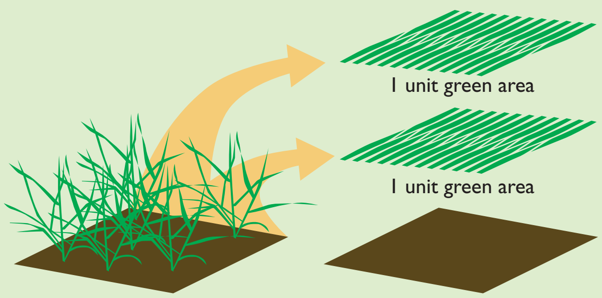
There are three distinct phases of canopy expansion and senescence:

- **Canopy expansion occurs slowly until GS30.**
- **Canopy expansion continues rapidly from GS30 to GS59.**
- **Senescence begins soon after ear emergence.**

Canopy refers to all the crop's green surface area (leaves, stems, ears and awns), with leaf blades forming the largest area.

Canopy size can be expressed as *green area index* (GAI) – the ratio of green area (one side only) to the ground area occupied.

Illustration of GAI = 2 – two areas of green leaf and stem to one area of ground



Early canopy expansion

Leaves and tillers emerge through the autumn and winter. At this time the crop is small and intercepts little light. Cool temperatures and low light levels slow leaf emergence, tillering and growth during this period.

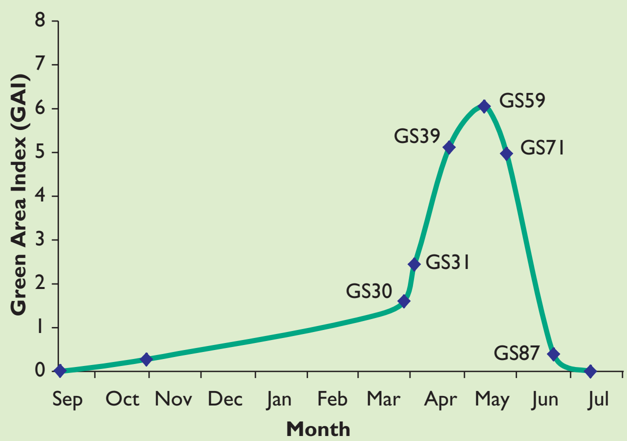
GAI = 1.4 by GS30 (2 April)

Rapid canopy expansion

From GS30 at the end of March/early April, canopy expansion accelerates as tillering continues and leaf emergence increases with rising spring temperatures. Canopy expansion continues until shortly after ear emergence.

Between GS30 and ear emergence, crop growth equates to an average of 1 unit of GAI every 12 days. Growth is most rapid from GS31 to GS39 when GAI increases by 1 unit every week. 'Canopy closure' occurs when the ground is completely shaded by leaves.

Change in GAI over the growing season



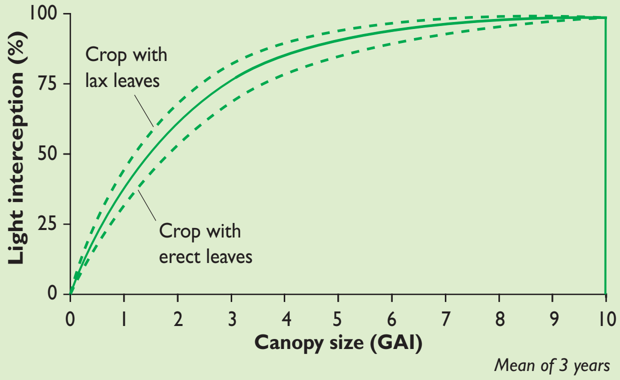
Mean of 3 years

Canopy closure* (GAI 3) = 21 April
North = 22 April
South = 20 April

* 5 days after GS31

Peak GAI at GS59 = 5.8

Light interception increases with canopy size



As the canopy becomes thicker, each increase in GAI intercepts less light energy, until full light capture is achieved. For example, an increase from GAI 2 to 3 captures 15% more light, whereas only 2% extra is captured as GAI rises from 6 to 7.

Canopy senescence

Loss of canopy green area begins soon after ear emergence as lower leaves progressively die. GAI falls from 3 to less than 1 in just 10 days.

GAI = <0.5 by 5 July
North by 16 July
South by 27 June

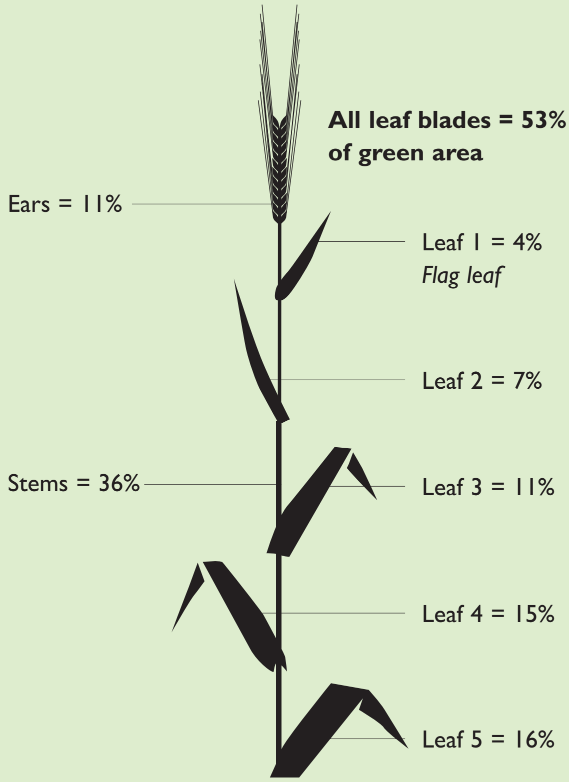
Spring barley

Canopy expansion tends to be slightly more rapid than that in winter barley.

Peak green area index in spring barley is 15% to 20% less than in winter barley (ie 5 units of GAI at GS59).

Distribution of green area

In barley, each successive emerging leaf has less green area. The flag leaf is usually half the area of leaf 2. By contrast, in wheat the large flag leaf intercepts most of the light. Lower leaves of barley are more important for light interception after flowering than in wheat.



Action

Reduce spring N if canopy size is excessive to prevent excessive tillering and lodging.

Ensure crops have adequate N at GS30 to achieve required canopy size.

For future years
Consider options to increase canopy size, if necessary:

- **sow early**
- **use high seed rates**
- **apply spring N early.**

Dry weight gain

Growth can be assessed by measuring changes in above-ground dry matter over time.

Barley growth is maximised in bright, cool weather.

Key Facts

- **Growth is slow before the canopy closes.**
- **Greatest growth takes place after the canopy has closed.**
- **Crop dry weight gain slows mid-way through grain filling after considerable canopy senescence.**

Growth up to canopy closure

Between sowing and canopy closure (about 5 days after GS31) some 18% of total *dry matter* is produced. Growth is slow. This period can extend up to 200 days as the canopy is incomplete.

Growth before canopy closure = 2.7t/ha
by 21 April

Growth after canopy closure

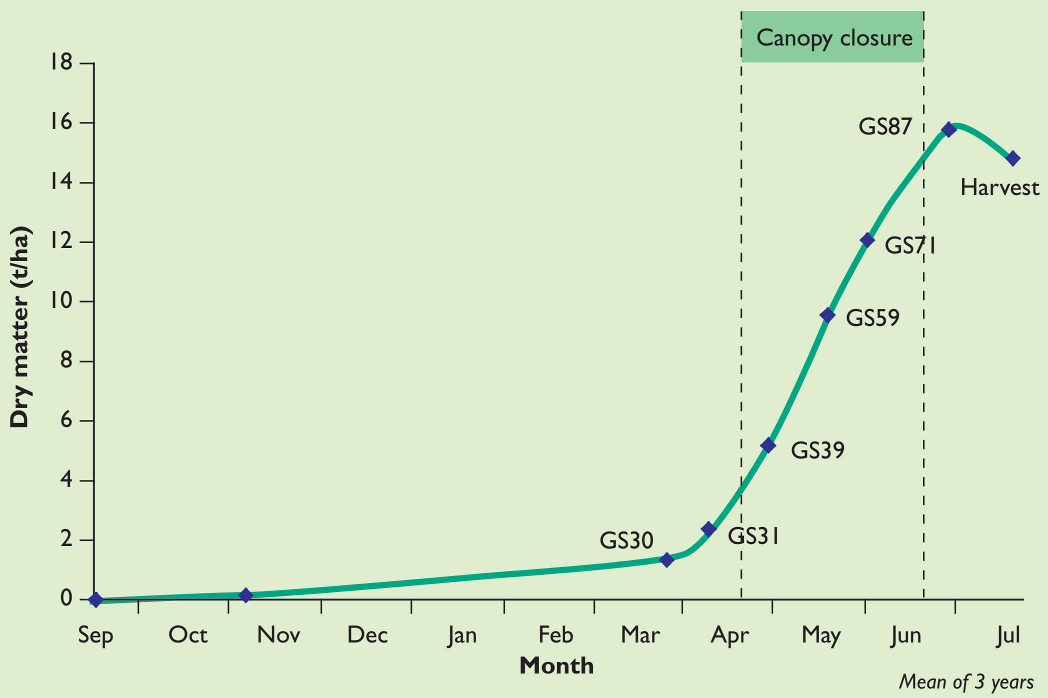
A GAI of over 3 is maintained for 8 weeks. During this period the crop generates about 70% of its total dry matter. The length of this phase is largely governed by temperature.

During this phase the crop intercepts more than 70% of available light for photosynthesis. Light availability affects the rate of dry matter accumulation. Cloud cover can reduce light energy by 75%.

The canopy begins to senesce at GS59, but dry matter gain hardly decreases until mid-way through grain filling.

Growth after canopy closure (GAI >3) = 0.2t/ha/day dry matter
an extra 11t/ha by 20 June

Change in crop dry weight over the growing season



Dry matter redistribution during grain filling

Dry matter continues to accumulate in the ear until GS87 while stems and leaves lose weight through respiration and retranslocation of carbohydrate reserves and nitrogen into the developing grain.

Leaves lose dry matter, then stems lose soluble reserves after GS71 – when final internodes stop extending.

Maximum crop dry weight occurs at GS87, the end of grain filling. Then dry weight falls as leaf tissue is shed before harvest.

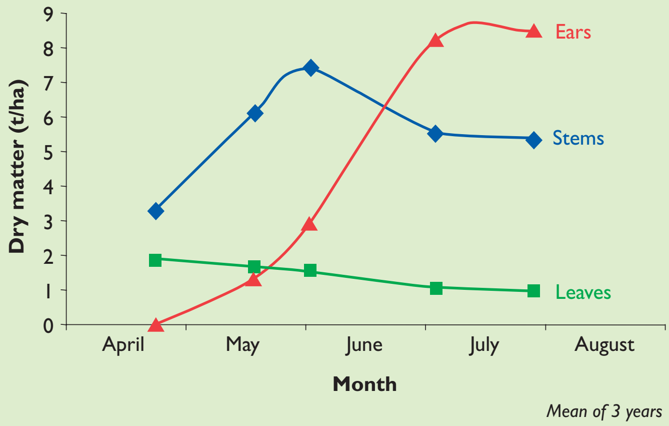
Stem and root diseases

Take-all (*Gaeumannomyces graminis*), eyespot (*Pseudocercosporella herpotrichoides*) and other stem-base diseases may restrict water and nutrient uptake and curtail growth crop growth. Barley usually follows wheat in arable rotations, increasing disease pressure. Growing barley as a first cereal helps to reduce yield losses caused by these diseases.

Foliar diseases

Foliar diseases, eg *Rhynchosporium*, net blotch and mildew, reduce canopy size and also curtail growth. Disease control measures protect leaf area and minimise disease impact on shoot number, grain number/ear and grain weight.

Dry matter accumulation of stems, leaves and ears over time



Spring barley

Maximum dry weight in spring barley (12.5t/ha at GS87) is about 80% that of winter barley.

Action

Adopt measures to hasten canopy closure in spring if necessary.

Control diseases to preserve green leaf area.

Control rabbits and slugs to protect young tillers in autumn and winter.

Consider autumn disease control if growth is poor, or tiller survival is threatened.

<u>For future years</u>
Consider earlier drilling if canopy develops late.

Crop height

Height is influenced by variety choice and agronomic practice.

Height influences lodging risk which can be reduced by plant growth regulators.

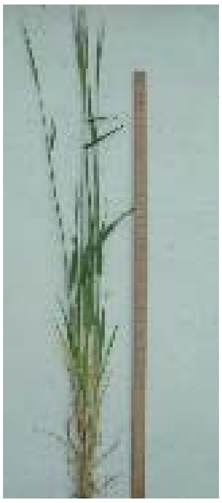
Key Facts

- **Crop height is determined by the extension of the last 5 *internodes*.**
- **Variety and growing conditions affect height.**

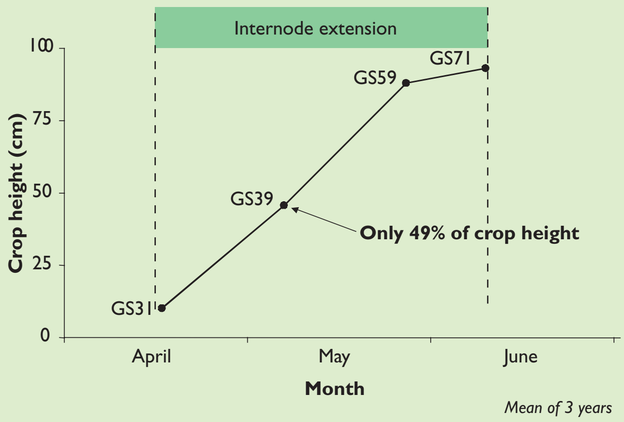
Height and node number

At GS39, a barley crop has only reached half of its final potential height. Agronomic conditions and crop management will influence final height.

By GS59 only small increases in crop height occur.



Crops grow taller as internodes extend



Nodes in extended stem = 4
5 internodes

Final height* = 93cm
North = 89cm
South = 98cm

* Height measured from soil level to collar of ear
PGRs = chlormequat at GS30-31, Terpal at GS37–39

Lodging risk

Barley generally has weaker stems than wheat. The crop is more susceptible to stem lodging at the base as well as brackling/necking further up the plant. Key risk factors include:

- **varieties** – vary significantly in lodging resistance. *HGCA Recommended List 2005/06* scores ranged from 4 to 9. Pearl is towards the upper end of current varieties.
- **soil mineral N** – at high levels promotes thick dense canopies susceptible to stem lodging.
- **fertiliser nitrogen** – applied early, or in excessive amounts, increases tiller numbers and reduces stem strength.
- **late sowing** – generally reduces lodging risk.
- **high plant populations** – increase lodging risk, mainly due to reduced anchorage strength.
- **poorly-structured soils** – provide weak anchorage and increase root lodging risk.

Plant growth regulators can be used between GS30 and GS45. Later treatments containing 2-chloroethyl phosphonic acid can reduce crop height by up to 15cm. Chlormequat has proved less effective at reducing height and lodging in barley than in wheat.

Spring barley

Variety and season affect spring barley height. The use of dwarfing genes in breeding programmes has reduced the height of many varieties. Spring crops are usually 5cm shorter than winter ones. PGRs are not usually required.

Action

Consider varietal lodging risk when planning cropping.

Assess lodging risk early in the season, before GS30.

Use PGRs when appropriate.

Stem carbohydrate storage

Reserves, mainly sugars (fructans), reach a maximum shortly after flowering.

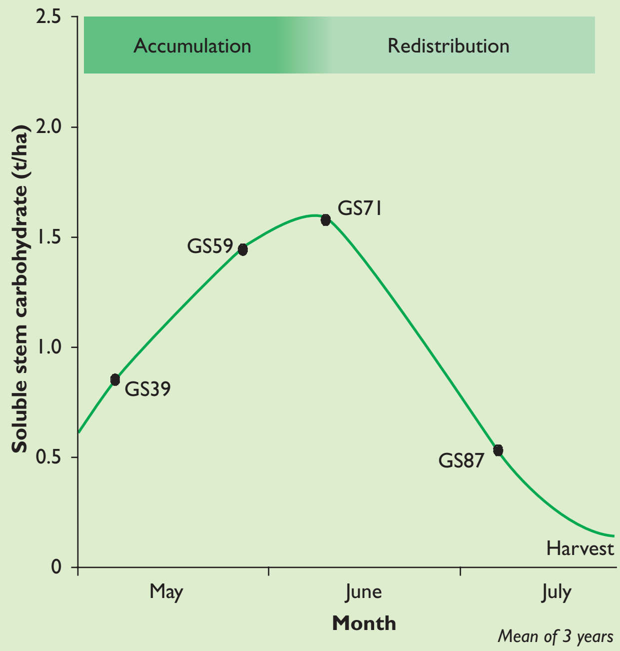
Key Facts

- **Stem reserves buffer the crop against poor growing conditions at grain filling.**
- **Grain fill depends on photosynthesis and reserves.**

Stem reserves

Stem reserves reach a maximum nine days after GS59 – the end of ear emergence. Variety and growing conditions affect the reserves.

Accumulation and redistribution of stem carbohydrates



	Stem dry matter (t/ha)	Soluble stem reserve (t/ha)
North		
GS39 (9 May)	3.1	0.9
GS59 (30 May)	5.7	1.3
GS71 (11 June)	6.8	1.7
GS87 (14 July)	5.3	0.4
South		
GS39 (3 May)	3.1	0.8
GS59 (21 May)	5.7	1.1
GS71 (5 June)	6.9	1.8
GS87 (28 June)	5.1	0.3

Comparison of stem reserves in north and south

Taller crops have more structural stem material. Stem height does not reflect stem reserves.

Reserves at flowering = 1.6t/ha

Grain filling and yield

Reserve redistribution begins after grain filling starts, accounting for a decrease of about 1.5t/ha in dry stem weight between flowering and harvest.

Stem reserves contribute 20% to 50% of total yield. In crops under stress, eg drought or pest attack, stem reserves contribute a higher proportion. Reserves make a smaller contribution to yield where post-flowering canopy survival is good.

Ear formation and grain filling

The storage capacity of each ear is determined by grain size and grain number on the ear.

Grain number has more effect on yield than grain size.

Key Facts

- **Potential grain number/ear is determined before flag leaf emergence during spikelet initiation.**
- **Ear weight increases rapidly after GS71.**
- **Grain filling determines grain size and final yield.**

Grain number determination

The number of grains on each ear depends on the number of fertile *spikelets* on the *rachis* – the central 'stem' of the ear. In barley, each spikelet contains only one *floret*, while wheat spikelets contain two to five fertile florets.

In two-row barley, spikelets form in threes. However, only the floret in the central spikelet is fertile. In six-row barley, florets in all three spikelets are fertile.

Crop management, particularly nutrition, can significantly influence grains/ear and ears/m^2. Together these determine the number of grains/m^2.

Grains/m^2 and the size of individual grains determine storage capacity during grain filling.

In winter barley, grain yield is more strongly related to grain number than grain size. Therefore, early management decisions to optimise tiller production and survival are particularly important.

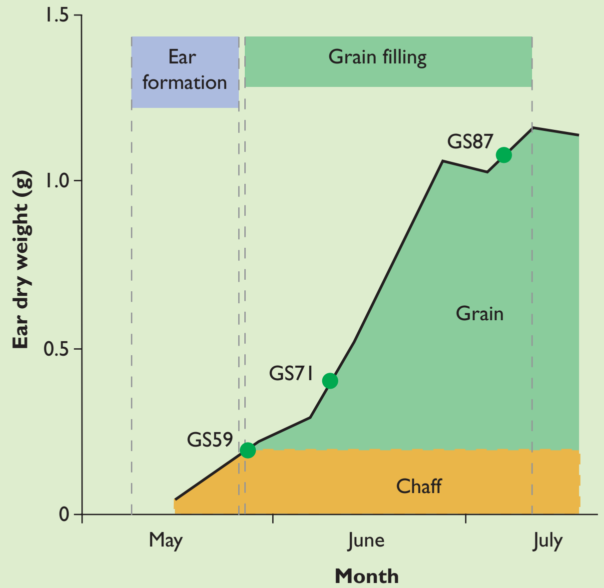
Flag leaf to ear emergence = 20 days

Grain number/ear = 24
North = 25
South = 24
Average of main shoots and tillers at harvest

Ear weight

By flowering the ear comprises florets containing grain, glumes and rachis. Grain dry weight increases slowly at first and rapidly after GS71. While grain weight increases, the weight of other parts remain almost unchanged.

Ear weight increases rapidly after GS71



Mean of 3 years

Ear weight at flowering = 0.16g/ear

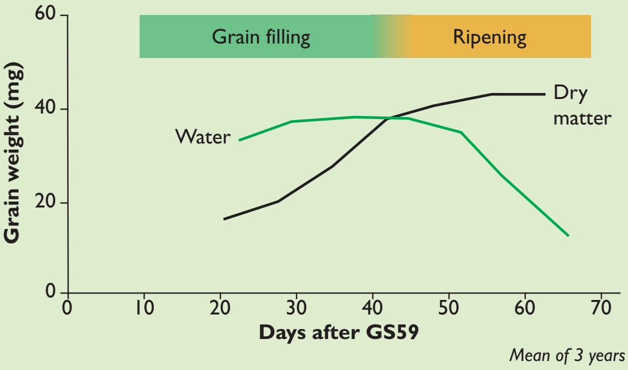
Ear weight at harvest = 1.11g/ear

Grain filling and ripening

Ear and leaf photosynthesis and redistribution of stem reserves are all-important in the 6–7 week grain filling period.

Grain *ripening* takes a further 2–3 weeks. During this period dry matter content increases and water content decreases.

Grain weight and water content



Final grain dry weight, appearance and specific weight are all determined during grain filling. Benchmark data are for six grains from the central part of the ear.

Dry matter = 39mg/grain
North = 41mg
South = 38mg
40 days to 5 July

Canopies lose most greenness in the two weeks before grain weight reaches its maximum.

GAI = <1
3 days before maximum grain weight

After filling, moisture content provides the best index of ripening until grains are dry enough to harvest. Moisture content declines as dry matter accumulates in the grain (70%–45%), then down to 20% due to water loss.

Ripening period = 20 days

Spring barley

On average, spring barley varieties produce 19–24 grains/ear – fewer than in winter barley.

New varieties and improved management have led to increases in thousand grain weight (TGW) over recent years. Values are now similar to those of 2-row winter crops. Higher TGWs tend to occur in the north than in the south.

Yield

Marketable grain yield represents about half of the total above-ground crop dry matter produced.

Grain weight and size, as well as ear number/unit area, all determine final marketable yield.

Key Facts

- **Total crop dry weight indicates likely yield because 'harvest index' is relatively stable.**
- **Grain yield is made up of:**
  - **ears/m²**
  - **grains/ear**
  - **average grain weight.**

Harvest index

The *harvest index* (ratio of grain weight to total above-ground crop weight) varies relatively little between site and season, unless serious lodging, late-season drought or disease significantly reduce grain filling.

Small seasonal variations in harvest index can occur, for example, it may reduce if good growing conditions up to flowering are followed by dull weather. This limits photosynthesis during early grain-filling when potential grain size is determined.

Harvest index can vary between varieties.

Crop dry weight at harvest = 14.8t/ha

of which:

Grain = 51%

Stem and leaf material = 43%

Chaff = 6%

Grain yield

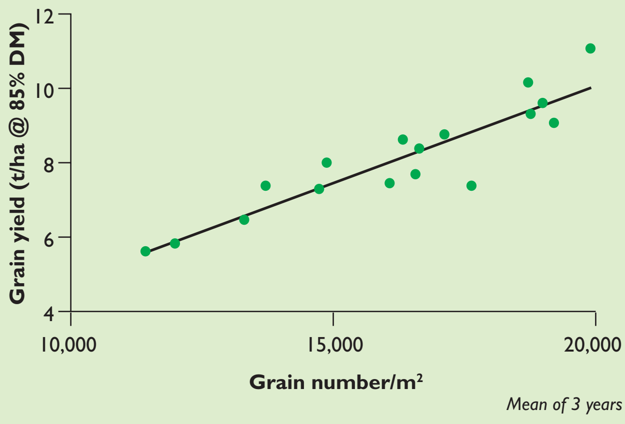
Final grain yield is made up of three components, the most stable of which for a given variety is average grain weight.

Final grain yield = Ears/m² x Grains/ear x Average grain weight

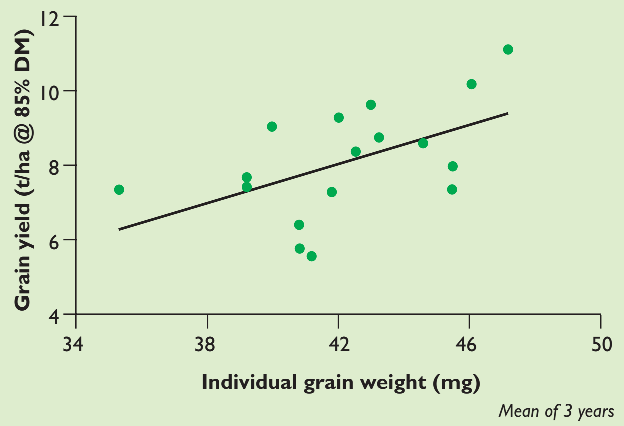
Most yield variation between sites and seasons reflects differences in grain number rather than grain size.

There is a strong relationship between grain number/m² (ears/m² x grains/ear) and yield, but only a weak relationship between average grain weight and yield.

Contribution to yield of grain number/m²



Contribution to yield of grain weight



High yields depend on sufficient numbers of ears, and crop managers should aim to maximise growth as ears form. Some compensation for low ear numbers can occur; crops with relatively few shoots produce more grains/ear.

Barley only has one fertile floret/spikelet, so yields do not recover as much as is possible with wheat. Fewer spikelets (and hence florets) abort in crops with few ears.

Late-season drought, lodging or disease all impair photosynthesis and hence can reduce grain filling.

Spring barley

Spring barley yields about 20% less than winter barley, although the difference is smaller in the north than in the south.

In spring barley, 30-35% of grain carbohydrate comes from the flag leaf and *peduncle*, 25-45% from the ear and 20-45% from the rest of the plant.

- **Grain yield = 8.8t/ha**
  85% dry matter
- **Ears/m^2 = 775**
- **Grains/ear = 24**
- **Average grain weight = 46mg**
  85% dry matter

Action

Manage crops early in the season to ensure high grain number/m^2 and so high yield.

Maintain canopy lifespan through control of late-season disease, to maximise grain filling.

Harvest as soon as possible after the crop is ripe to reduce harvest losses.

Grain quality

Feed barley is usually purchased on a minimum specific weight basis.

Malting markets have specific requirements. Key characteristics are variety, germination, nitrogen content and grain size (www.ukmalt.com).

Key Facts

- **Nitrogen content can be manipulated for specific end-user quality specifications.**
- **Most feed grain buyers specify specific weight.**

Six-row varieties with high grains/ear and grains/m² tend to produce smaller grains with lower specific weights and more screenings than two-row varieties.

The relatively longer grain filling period in northern Britain reduces these differences. Two-row winter barley and spring barley varieties produce similar specific weights and screenings.

Protein content

During grain filling N is redistributed from stems, leaves and chaff to the grain. Root systems remain active during grain filling, so high soil N availability late in the season can lead to high grain N.

Feed barleys can take up to 35kg N/ha from the soil after flowering. Malting crops take up less because N is applied earlier and at lower rates.

High grain N content arises from a large uptake or redistribution of N late in the season, or poor starch deposition.

High grain N can also result from drought, lodging or disease, all of which reduce yield without affecting N redistribution. In crops grown for high N specification, lodging risk may increase.

Grain N offtake = 132kg/ha
1.76% grain N

Benchmark data for grain quality characteristics*

	Overall	North	South
Yield (t/ha)	**8.8**	9.0	8.5
Average grain weight (g @ 85% DM)	**46**	48	45
Grain N (%)	**1.76**	1.73	1.80
Specific weight (kg/hl)	**65.0**	65.0	65.0

*Values for crops grown for feed.

Spring barley

Grain nitrogen concentrations of malting varieties, grown in low nitrogen fertiliser regimes, tend to be lower in the north than in the south. The reason may be that greater yield dilution of grain nitrogen occurs in the north, where most spring malting barley is sold for malt distilling, with 70% of grain nitrogen concentrations below 1.65%.

Most spring malting barley grown in England is destined for brewing, with 70% of grain nitrogen concentration requirements in the range 1.55% to 1.85%.

Specific weight and screenings

Specific weight, a measure of individual grain density and how they pack, is influenced by grain fill, grain size and surface characteristics. Large, well-filled grains have a high malt extract potential. Therefore, screenings need to be minimised.

Small-grained varieties are often associated with high screenings. Grains from the upper and lower parts of ears, as well as from late-formed tillers, tend to be smaller than those from the central part of the ear.

Action

Apply all N fertiliser to winter malting crops at or before GS31 to reduce the risk of excess grain N concentration.

Apply all N fertiliser to spring crops at or before leaf 3, unless high grain N is required.

Sow spring varieties that are vulnerable to high screenings as early as possible.

Avoid high seed rates or late sowing of spring barley to minimise screenings.

Taking measurements

Benchmark values given in this guide can be used in support of husbandry decisions by making comparisons with your own crops, if careful field observations and measurements are made.

To represent a crop take at least four samples – one from each quarter of the field. In a variable crop, take more samples. Avoid atypical patches, eg headlands and gateways.

Assessing 'Growth Stages'

Use the decimal growth stage code* (see pages 4 and 5) and only assess main shoots until flag leaves emerge. To determine crop growth stage, use the median (middle) stage from an odd number of plants arranged in order, eg if five plants are at GS33, GS37, GS37, GS39 and GS39, the crop is at GS37.

Plant population

Take at least four samples (more if variable) across the field. Throw down a quadrat (square frame) and count plants inside it. Divide by the area (m^2) of the quadrat to get plants/m^2. Alternatively, count plants growing along a measured length of row; divide by the row width (m) and length (m) to determine plants/m^2.

Use the same method to work out shoot numbers/m^2, counting shoots instead of plants.

Crop canopy

Measure crop canopy as Green Area Index (GAI), ie surface area of green material (one side only) divided by ground area occupied. If all leaves, shoots and ears from $1m^2$ of a field, separated and laid out adjacent and flat, cover $2m^2$, then GAI = 2. If they cover $4m^2$, GAI = 4.

Alternatively, it is possible to assess the GAI by comparison with crops of known GAI (see below).

Dry weight

Dry weight is less easy to assess in the field than canopy size.

Crop biomass can be measured by throwing down a quadrat, removing the crop and then drying it.

One option for drying is:

1. Place harvested material in a microwave at high power for 10–15 minutes.
2. Turn 2–3 times during drying.
3. Weigh dried weight (g) accurately.
4. Divide dried weight by quadrat area (m^2) to get biomass (g/m^2).
5. Divide by 100 for biomass (t/ha).

Ear dry weight measurements can help predict yield after the grain has reached 45% moisture content.

To do this, dry and weigh a known number of ears at around 45% moisture content (as 1–3 above), then:

1. Divide by ear number and multiply by 0.90 to correct for chaff.
2. Multiply by fertile shoot number/m^2 to give estimated grain yield (g/m^2).
3. Divide by 100 for yield (t/ha).

GAI = 1

GAI = 2.2

GAI = 3.5

* Tottman, D.R., Makepeace, R.J. and Broad, H. (1979) An explanation of the decimal code for the growth stages of cereals, with illustrations. Annals of Applied Biology **93**:221-234.

Glossary

Benchmark – a quantitative reference point against which a crop's performance can be compared.

Canopy – all green surfaces of the plant capable of photosynthesis including stems, leaves, ears and awns. Canopy is usually measured in units of GAI.
Key stages are:
- canopy closure, usually a week after GS31 when GAI = 2.4
- canopy expansion
- onset of senescence.

Coleoptile – the first shoot to emerge from the seed. The first true leaf emerges through the coleoptile.

Development – changes in crop structure, as defined by the Decimal Code (pages 4–5).

Dry matter (DM) – all crop constituents, other than water, left after the tissue has been dried by a standard method to constant weight.

Floret – a single flower containing a single grain.

Green Area Index (GAI) – the ratio of the area of all green tissues (one side only) and the equivalent ground area occupied – a measure of canopy size.

Growth – changes in crop size or weight.

Growth phase – period during which a specific crop structure is produced.

Growth stage – a finite point in a crop's development – as described on pages 4–5.

Harvest index – the ratio of grain weight to above-ground crop weight.

Imbibition – initial uptake of water by dry seed.

Internode – the hollow length of stem between two nodes.

Leaf sheath – the basal portion of a leaf which encloses the stem and sheaths of younger leaves.

Node – the point at which a leaf sheath is attached to the stem.

Peduncle – the topmost node between the flag leaf node and the base of the ear – the collar.

Photosynthesis – formation of sugars by green tissues from absorbed carbon dioxide and water and driven by energy from sunlight.

Phyllochron – the time taken for each leaf to emerge, measured in thermal time.

Rachis – the portion of the stem within the ear bearing the spikelets.

Ripening – a loose term describing the changes that occur in grain between completion of growth and maturity. These include drying and development and loss of dormancy.

Senescence – loss of greenness in photosynthetic tissues, normally the result of ageing. Also caused by disease or drought.

Shoots – all the stems of a plant with the potential to bear an ear – includes main stem and all tillers.

Spikelet – a structure containing one or more florets. In barley, there is only one floret in each spikelet.

Stem reserves – soluble carbohydrate stored in the stem which can translocate and contribute to yield.

Thermal time – the sum of all daily temperatures (mean of minimum and maximum) above a base temperature at which a process stops. In the case of leaf development this is 0°C. Results are expressed in day-degrees (°C days), as shown below:

Day	Mon	Tue	Wed	Thur	Fri	Sat	Sun
Temperature* (°C)	12	14	16	17	18	18	19
Thermal time (°C days)	12	26	42	59	77	95	114

*Average temperature over 24 hours.

Tillering – the production of tillers – side shoots to the main stem.

References

HGCA guides

The wheat growth guide, 1997

Introductory guide to malting barley – a guide, 2001

The grain storage guide, revised 2003

HGCA Recommended Lists (annual)

HGCA Project Reports

Available at cost from HGCA

119 Effects of site and nitrogen management on growth and grain quality for malting of winter barley

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HGCA Topic Sheets

Posted free to levy payers on request

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60 Ensuring good germination in malting barley

71 Managing spring barley to avoid physical defects

76 Managing spring malting barley for consistent grain characteristics

Websites

HGCA
www.hgca.com/research

Maltsters' Association of Great Britain
www.ukmalt.com
www.malt.info

SAC advice based on HGCA research
www.sac.ac.uk/consultancy/cropclinic/cropadvice/hgcaresearch

Acknowledgments

This guide was funded by HGCA and SEERAD (Scottish Executive Environment and Rural Affairs Department) and is mainly based on benchmark data obtained in a HGCA and SEERAD-funded project (HGCA project 2514, Project Report 384). The project was led by John Spink, ADAS. Other collaborators in the project and guide were Jonathan Blake, ADAS, Dr Ian Bingham and Dr Steve Hoad, SAC, and Dr John Foulkes, University of Nottingham.

The guide was edited by Dr Clive Edwards, HGCA and Geoff Dodgson, Chamberlain.

HGCA is grateful to many people who have commented on draft versions of the guide, including: John Garstang and Dr Roger Sylvester-Bradley, ADAS; Alan Bide and Peter Taylor, AICC; Dr Ethel White, DARD; Dr David Cooper, Defra; Peter Hanson, Prof Graham Jellis and Dr Roger Williams, HGCA; Ivor Murrell, MAGB; Prof Steve McGrath, Rothamsted Research; Dr Kerr Walker, SAC; Dr John Fowbert, SEERAD; and farmers Richard Brandram-Jones, Bryan Collen, Julian Hasler, Stuart Hutchings and Martin Manning.

Design by Chamberlain.

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